Development of Risk-Informed and Performance-Based (RIPB) Standards

- Opening Remarks by Mike Franovich, Division Director, NRR/DRA

- **Session Chair:** Matthew Humberstone, Senior Reliability and Risk Analyst, RES/DRA/PRB

- **Panelists/Speakers:**
  - Prasad Kadambi (ANS)
  - David Grabaskas (ASME/ANS JCNRM)
  - Andrew Whittaker (ASCE)
  - Rebecca Steinman (IEEE)
  - Tom Basso (NEI)
  - Eric Thornsbury (EPRI)

Presented to:
2023 NRC Standards Forum
September 13, 2023

Overview of ANS Activities to Support RIPB Standards

N. Prasad Kadambi

Chair, Risk-informed, Performance-Based Principles and Policy Committee (RP3C)

The ANS Standards Board Supports RIPB Standards To Modernize Nuclear VCS*

- Creation and operation of RP3C
- Current activities of RP3C
- ANS Standards Board (SB) has directed ANS consensus committees (CCs) to incorporate RIPB principles where appropriate.
- All eight CCs provide reports at every SB meeting.
  - The SB recognizes the varied application and applicability of such principles to each portfolio of standards.
  - Relative to advanced reactors, the Joint Committee on Risk Management (JCNRM) plays a central role in supporting modernization relative to RIPB standards development

*"Voluntary consensus standard" as defined in OMB Circular A-119 [1]. NOTE: Numbers in brackets refer to corresponding reference numbers on slide 11.

ANS Has Been a Leader in Promoting RIPB VCS

- Recent experience with conventional VCS shows that products that have detailed “shall” statements give rise to system requirements that are unnecessary or too conservative.
  - Frequently the motivation is driven by convenience for verification of compliance to requirements established by regulatory authorities.

- Conventional VCS often do not support economic deployment of advanced reactors mandated by the Nuclear Energy Innovation and Modernization Act (NEIMA) and supported by industry investments.
  - RIPB VCS provide a more logical fit with NEIMA than conventional ones.
  - ANS is in a good position to advocate for RIPB VCS by articulating specific aspects of the value proposition to move away from prescription.
  - ANS is actively tackling the challenges of creating guidance for RIPB VCS.

Current Activities Toward RIPB VCS

- ANS has recognized the need to create an infrastructure to support RIPB VCS.
  - Part of this is to focus on structured performance objectives such that varied levels of detail can be accommodated rigorously.
- The most visible of these activities are related to creating one or more internally consistent and coherent suites of standards that could foster further development of RIPB VCS within and outside of ANS.
- An existing example is the suite of seismic standards ANS-2.26 [2]*, 2.27 [3], 2.29 [4], and ASCE 43-05 [5].
- Currently, ANS efforts are focused on the series ANS-30.1 [6], 30.2 [7], and 30.3 [8].
  - ANS views these standards within a structure where success in issuing ANS-30.1 as a Guidance Standard, developing ANS-30.2, and obtaining regulatory endorsement of ANS-30.3 would be major accomplishments toward RIPB VCS.

*Titles of standards are provided on slide 11.

What ANS-2.26 Does

ANS-2.26:
Assign a "Seismic Design Category (SDC):"

Given the potential consequences of failure, assign a performance criterion: specifically, a *failure probability criterion*.

The other standards then tell you how to go about engineering satisfaction of this criterion.

Figure from Appendix A:

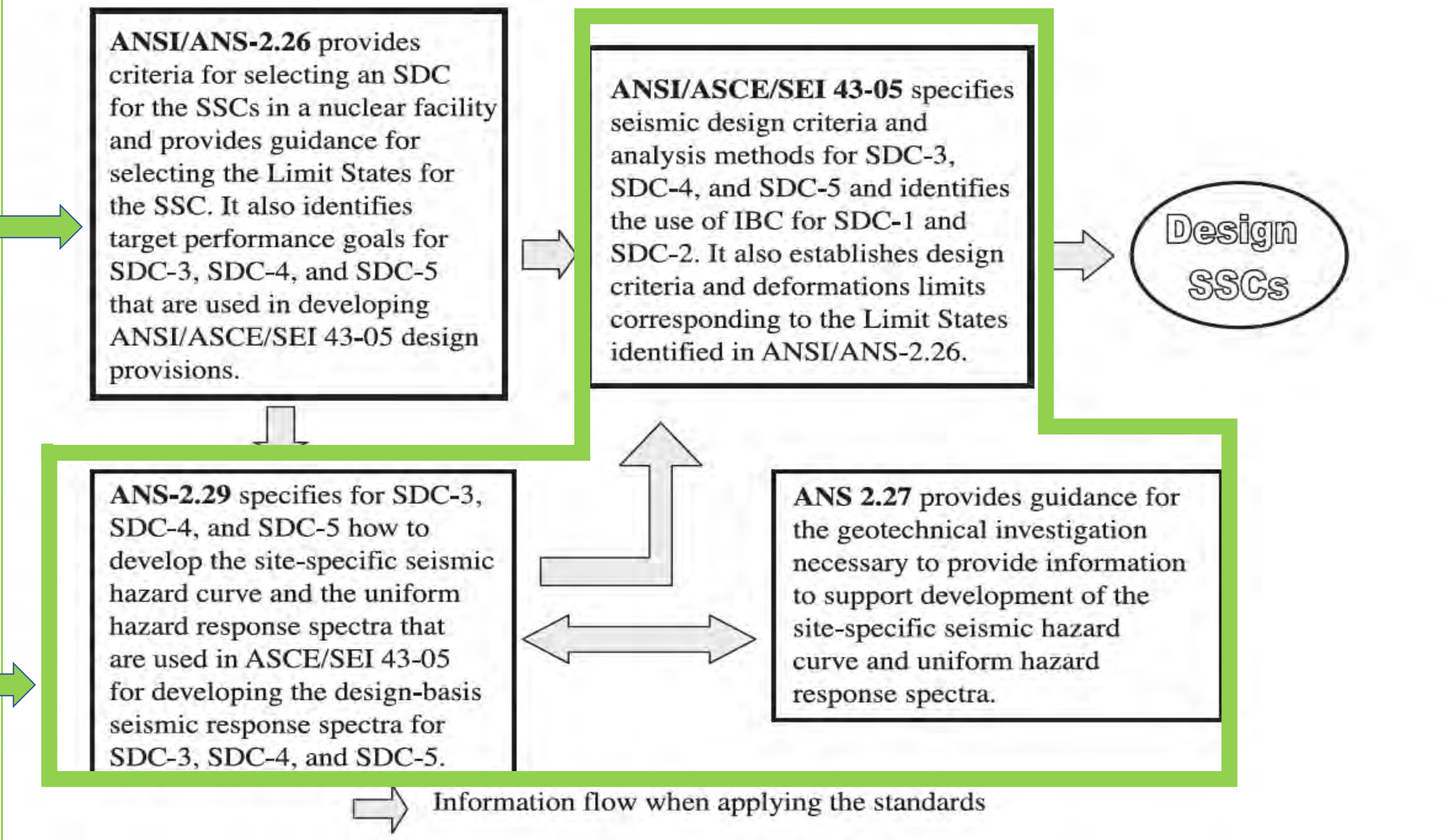
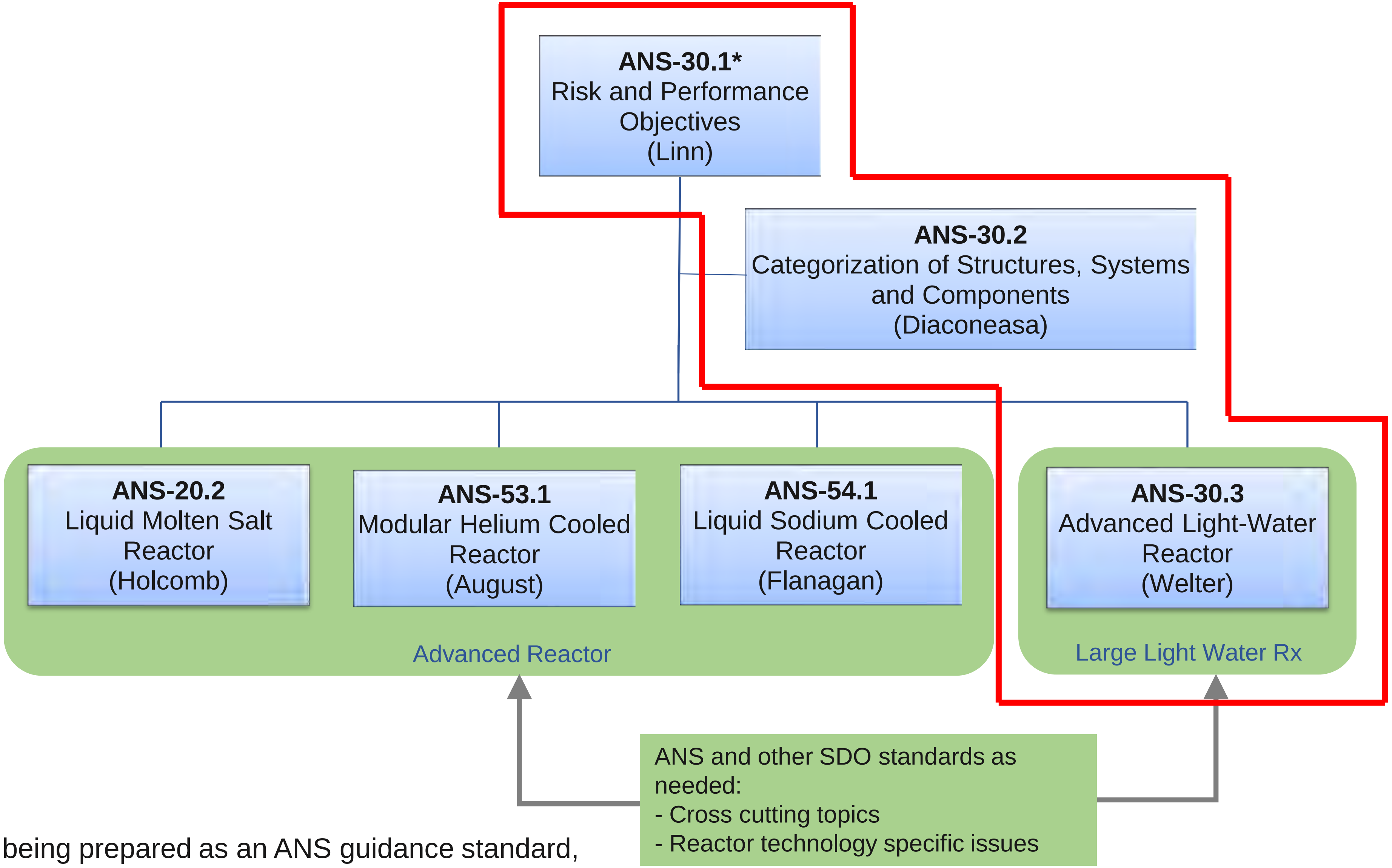


Figure A.1 — Schematic showing the relationships of the seismic standards

ANS Standards Committee Hierarchy For Advanced Reactors



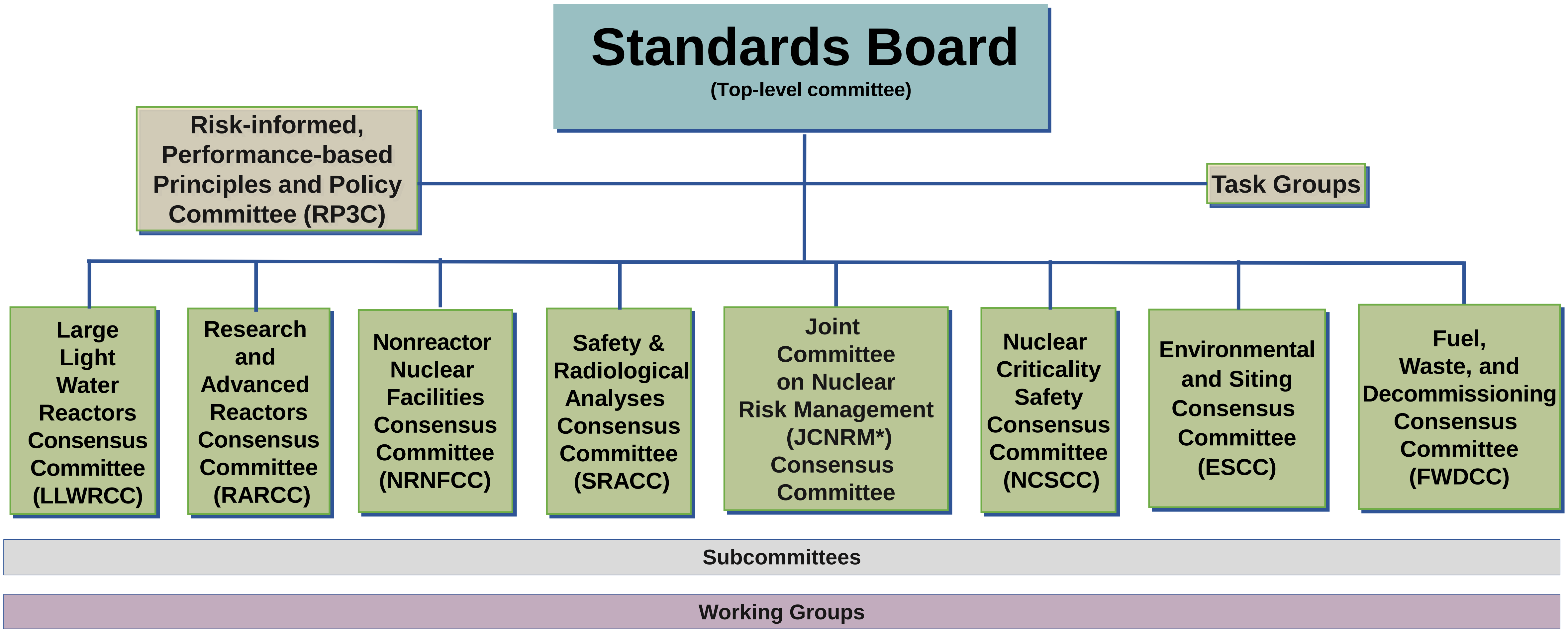
*ANS-30.1 is now being prepared as an ANS guidance standard, not as an ANSI consensus standard

NRC activities support RIPB, but more can be done.

- Commission approval of SECY-18-0096 [9] on “Functional Containment” has major significance for RIPB standards as an example of performance-based principles.
  - This clears the way for standards development organizations (SDOs) to consider all general design criteria from a performance-based perspective.
- Similarly, issuance of RG 1.233 [10] has significance because it is meant to be technology-inclusive for addressing certain major safety issues.
  - Logically, it means that light water reactors should also be able to use its provisions as one acceptable way to implement relevant regulations.
- NRC should recognize that industry and SDOs alike look for regulatory cues that may encourage or discourage RIPB VCS.
- NRC can do more to clarify how the provisions of NEIMA relative to a technology-inclusive regulatory framework will use appropriate VCS for conforming with OMB Circular A-119 [1].
  - Federal policy clearly favors performance-based requirements instead of prescriptive ones.

ADDITIONAL INFORMATION

The ANS Standards Committee



**The JCNRM is a joint ANS and ASME committee.*

Risk-informed, Performance-based Principles and Policy Committee (RP3C)

The ANS Standards Board established the RP3C to support modernizing of ANS standards. Activities for training and knowledge sharing of RIPB principles and practices are part of the scope. The RP3C is responsible for the identification and oversight of the development and implementation of RIPB approaches in ANS standards. The RP3C Community of Practice (CoP) is one of the more successful ongoing training activities. The CoP is held on the last Friday of a month and is open to all professionals interested in RIPB principles and practices. Nearly 40 CoP recordings since February 2020 are available at https://www.ans.org/standards/rp3c/cop/. Contact standards@ans.org for questions or to get on the list to receive announcements of upcoming presentations.

Titles of Cited Documents and Standards

[1] OMB Circular A-119, “Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities”

[2] ANSI/ANS-2.26-2004 (R2021), *Components for Seismic Design Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design*

[3] ANSI/ANS-2.27-2020, *Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessments*

[4] ANSI/ANS-2.29-2020, *Probabilistic Seismic Hazard Analysis*

[5] ASCE/SEI 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*

[6] ANS-GS-30.1-202X, Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs

[7] ANS-30.2-202X, *Classification and Categorization of Structures, Systems, and Components for New Nuclear Power Plants*

[8] ANSI/ANS-30.3-2022, *Light Water Reactor Risk- Informed, Performance- Based Design*

[9] SECY-18-0096, *Functional Containment Performance Criteria For Non-Light-Water-Reactors*

[10] RG 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors”

ASME/ANS NON-LWR PRA STANDARD
IMPLEMENTATION EXPERIENCE

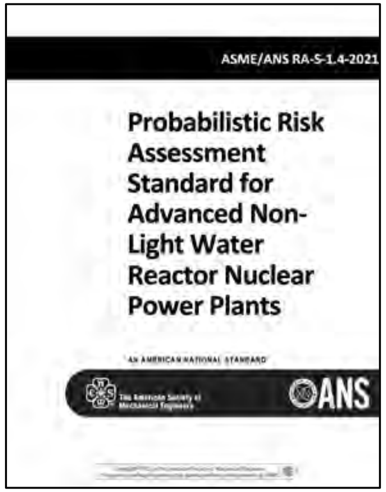
Dave Grabaskas
Manager, Licensing and Risk Assessments Group, Argonne National Laboratory
Chair, ASME/ANS Non-LWR PRA standard working group

JCNRM Background

- **Joint Committee on Nuclear Risk Management (JCNRM)**
  - The JCNRM is the PRA Standards development and maintenance consensus committee – formed by combining:
    - ANS RISC committee – originally developing the hazard PRA standards (e.g., Seismic, Fire, Flooding, etc.)
    - ASME CRNM committee – developed the internal events requirements.
  - Committees both started in the late 1990s, and officially merged around 2009, and issued the combined standard for LWRs covering L1 PRA, endorsed in RG 1.200.
  - Oversees two issued PRA standards (LWR – L1 and Non-LWR) and five under development.

Standard Background

- **Non-LWR PRA Standard Development**
  - o Working grouped formed in 2006
  - o Trial use standard issued in 2013
  - o New version formally approved by ASME, ANS, and ANSI in 2021
    - ASME/ANS/ANSI RA-S-1.4-2021
  - o Endorsed by the NRC in trial use RG 1.247 in 2022
  - o An integrated standard:
    - Covers from initiating events to offsite consequence
    - Can include any radionuclide source at the plant
    - From conceptual design to operation


ASME/ANS RA-S-1.4-2021

Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ANS


U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE 1.247

(For Trial Use)

ACCEPTABILITY OF PROBABILISTIC RISK ASSESSMENT RESULTS FOR NON-LIGHT-WATER REACTOR RISK-INFORMED ACTIVITIES

A. INTRODUCTION

Purpose

Implementation Experience

- **NRC Endorsement Process**
  - NRC staff involved throughout the standard development process, which greatly expedited NRC endorsement
  - Some disagreement regarding certain NRC positions; many resolved through collaboration, others further explored as part of RG trial use period
- **User Feedback**
  - Multiple non-LWR vendors are currently utilizing the standard as part of risk-informed performance-based design and licensing approaches, such as the Licensing Modernization Project (LMP)
  - Continual feedback from vendors regarding implementation experience

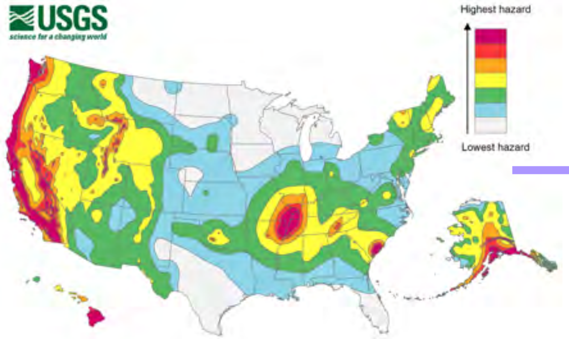
Implementation Experience

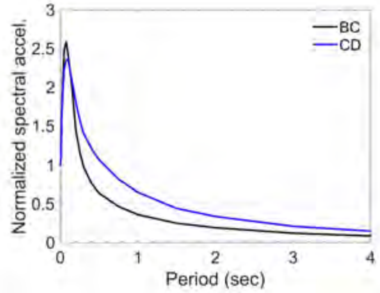
- **Standard and Applications**
  - As further experience is gained using the standard for risk-informed applications, potential discrepancies between standard requirements and application requirements are being identified
- **Seismic Requirements**
  - Gaining further insight regarding the practicality and implementation details of risk-informed seismic design
- **Innovative Uses**
  - Vendors utilizing deterministic or partially risk-informed approaches have been able to leverage certain elements of the standard (initiating events, mechanistic source term, radiological consequence, etc.)

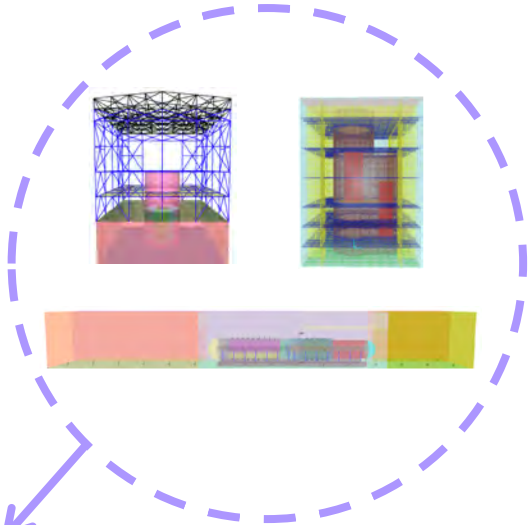
Treatment of extremes in RIPB design

Andrew Whittaker, Ph.D., S.E.
SUNY Distinguished Professor, University at Buffalo
Chair, ASCE Nuclear Standards Committee
Board of Directors, TerraPraxis

Standardization of design and licensing

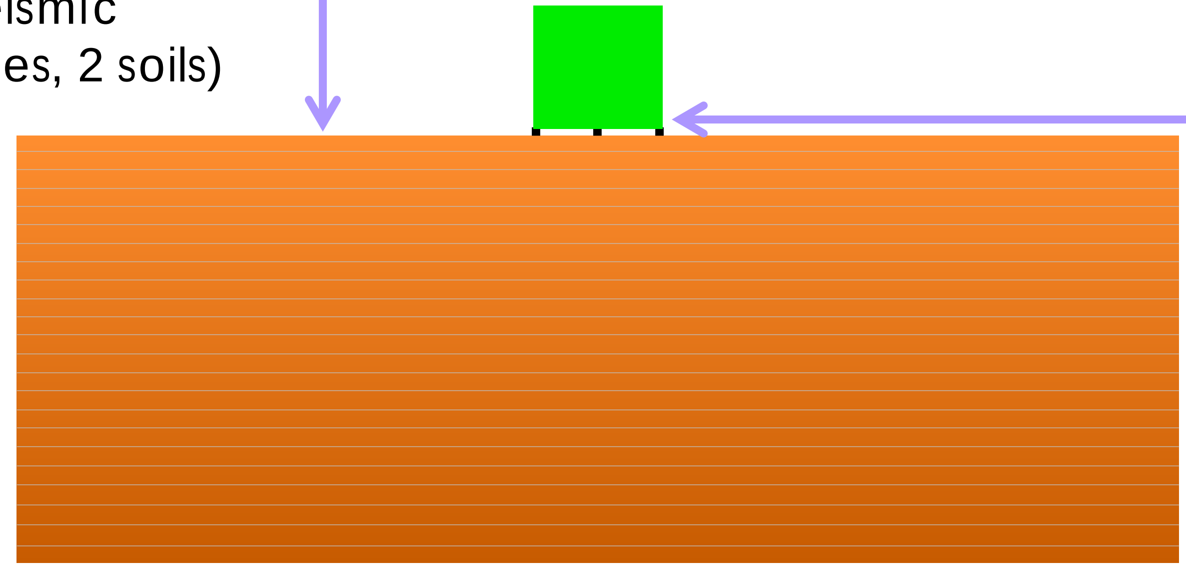


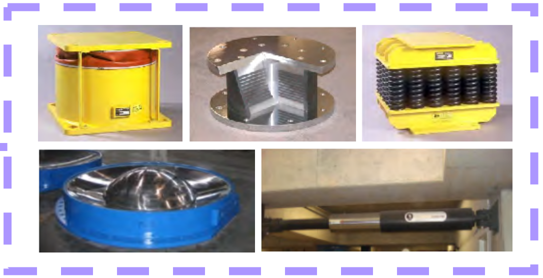




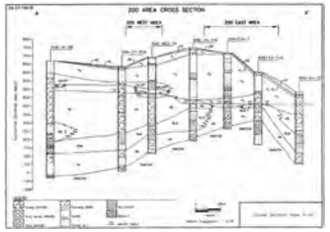
Licensed design spaces

Pre-binned seismic hazard (6 zones, 2 soils)





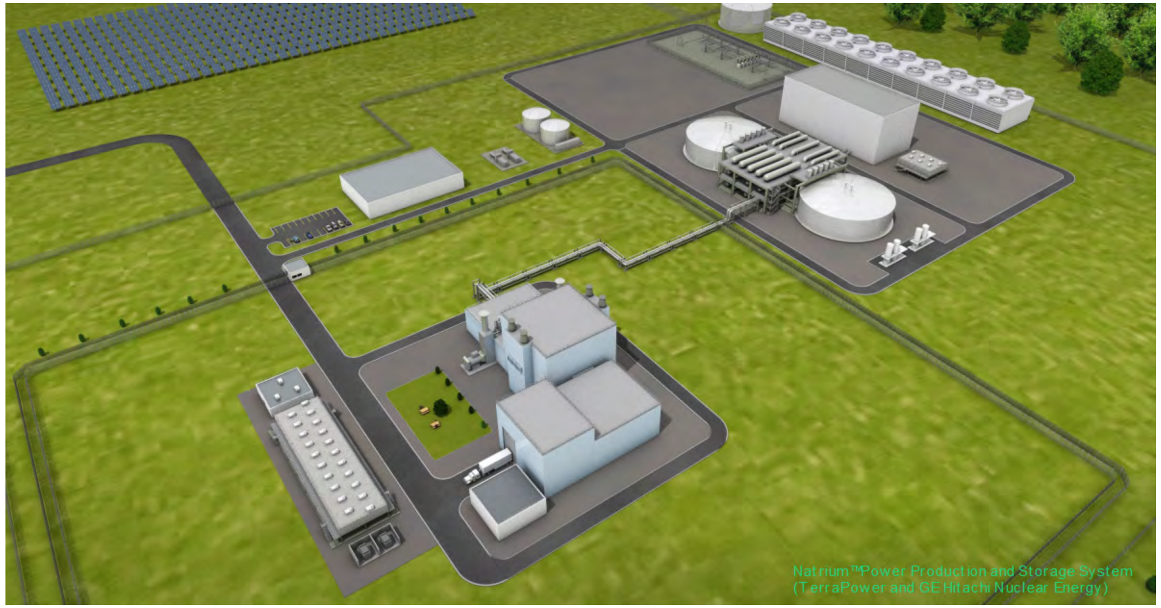
Licensed isolation systems



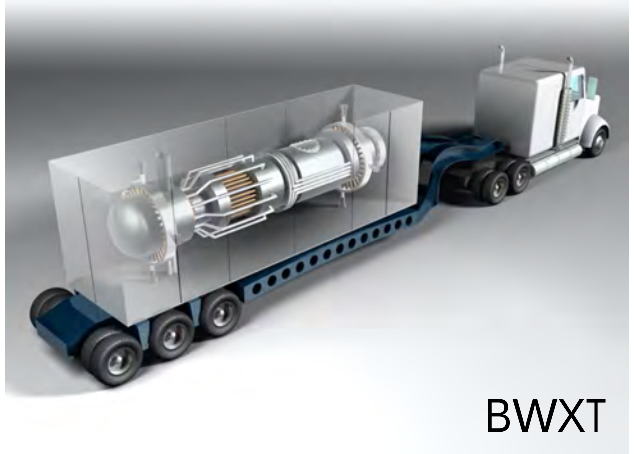
1) Site selected. 2) Pick a licensed heat source (MWe). 3) Pick a licensed isolation solution. 4) Price time and construction. 5) Evaluate alternatives and iterate on 2, 3, and 4.

Right sizing the treatment of extremes for next generation nuclear

TerraPower and GEH

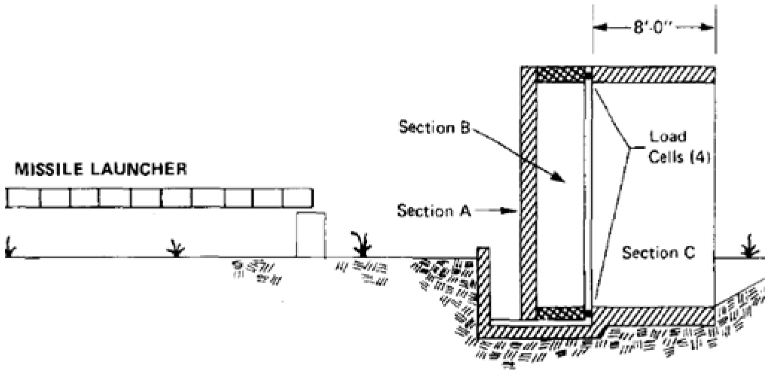


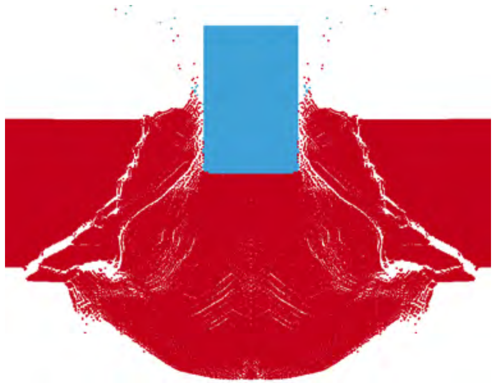
Lucid Catalyst

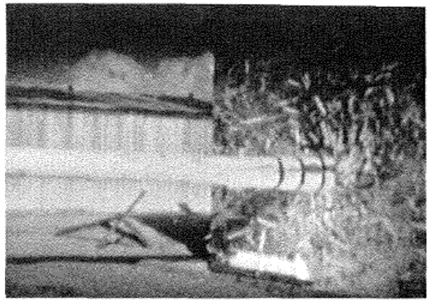


Extremes we must rethink in support of RIPB design

- Load effects
  - Wind-borne missile impact
    - Normal impact of high-velocity missiles
      - Schedule 40 steel pipe
      - Simple but why *normal* impact?
    - Any evidence in non-nuclear sectors of such damage?
  - Aircraft impact
  - Extreme ground shaking
- Acceptable risk



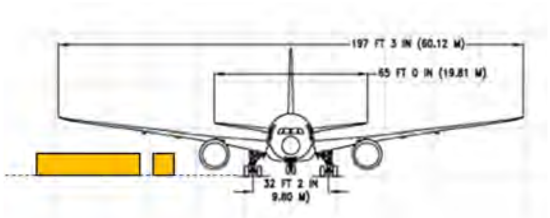


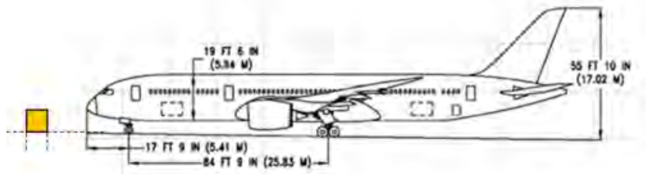


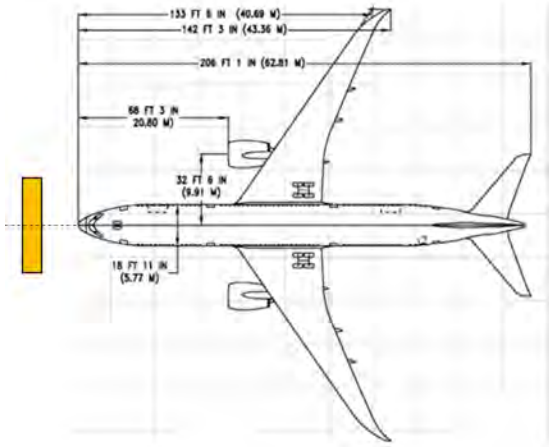
Stephenson, Terranova et al.

Extremes we must rethink in support of RIPB design

- Load effects: aircraft impact
  - Aircraft cockpits secured for 20 years
  - Hijacking of aircraft in US since 2001 = 0
  - Strike a RC box and not a political target? No.
  - Could you hit the RC box if you wanted to? No. See below.
  - MAF of aircraft impact on a RC box in the US = 0
  - Guaranteed fatalities from an aircraft strike? Yes
    - Missing target = 250+ dead on B787, all on the plane



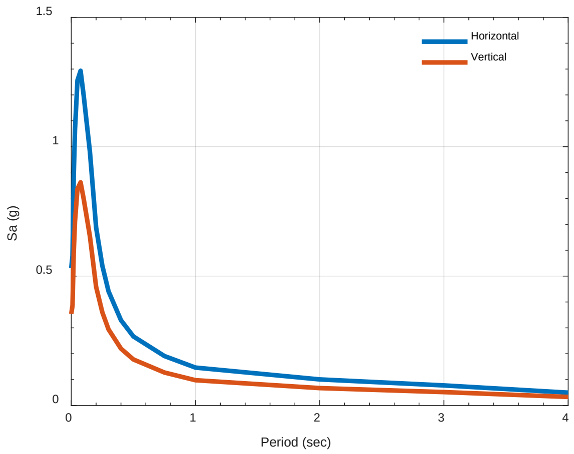


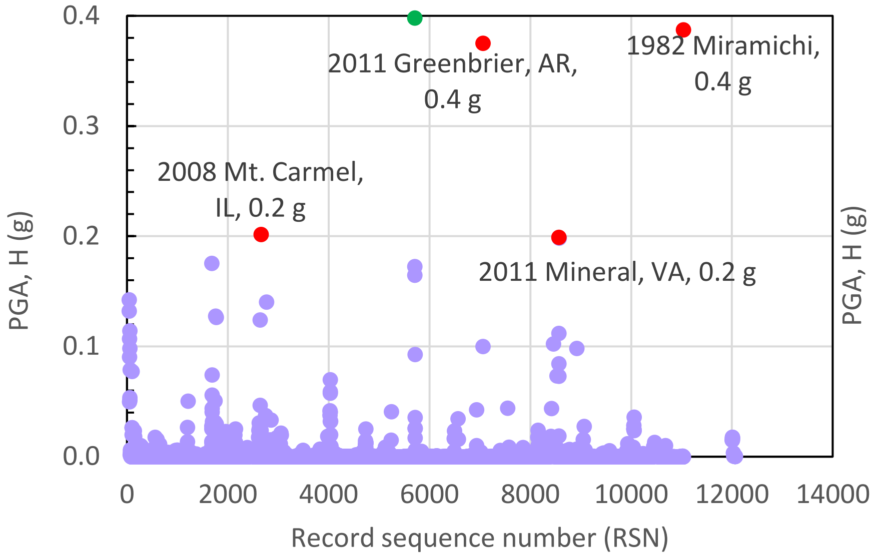


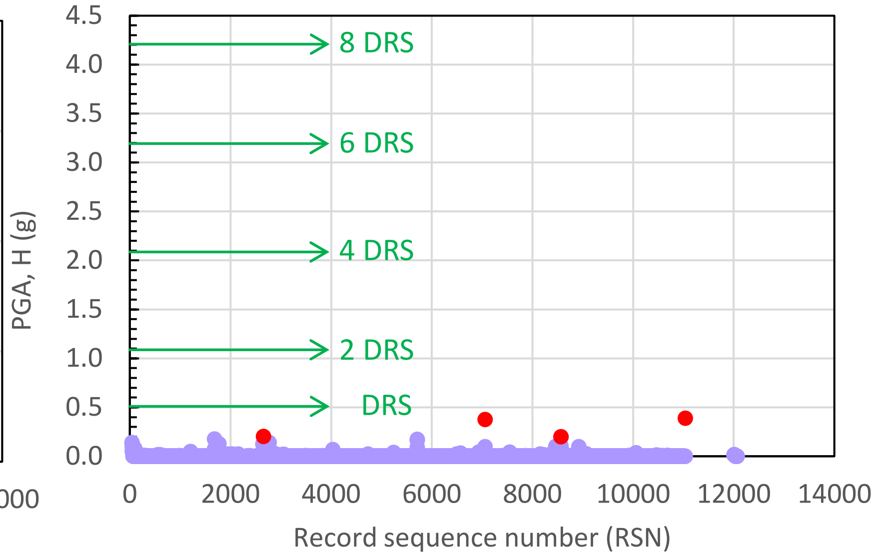
Boeing

Extremes we must rethink in support of RIPB design

- Load effects: *incredible* ground shaking
  - Consider Seismic Design Category 4, Clinch River
    - 100% DRS (PHA=0.53g, RP=5,300 years), 200% DRS (1.06g, 25,000), 400% DRS (2.12g, 150,000), 600% DRS (3.18g, 490,000), 800% DRS (4.24g, 1,250,000)







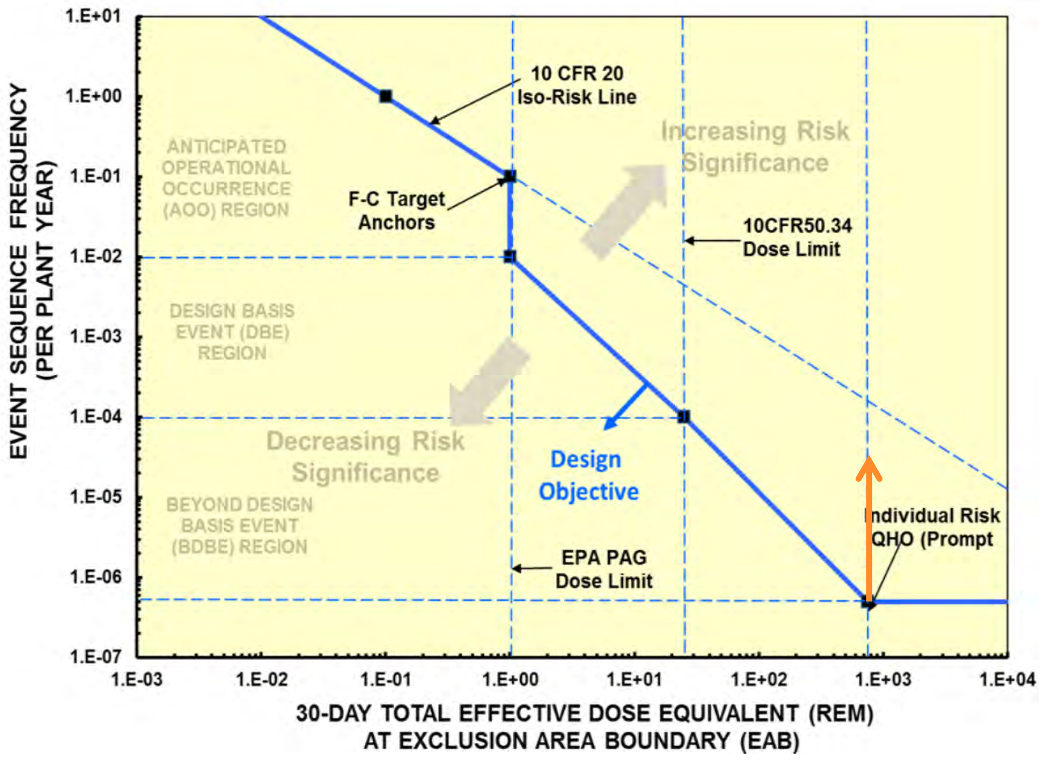
Outcomes of extreme: nuclear-related fatalities = 0

Fukushima Daiichi, 2011

TMI, 1979

Extremes we must rethink in support of RIPB design

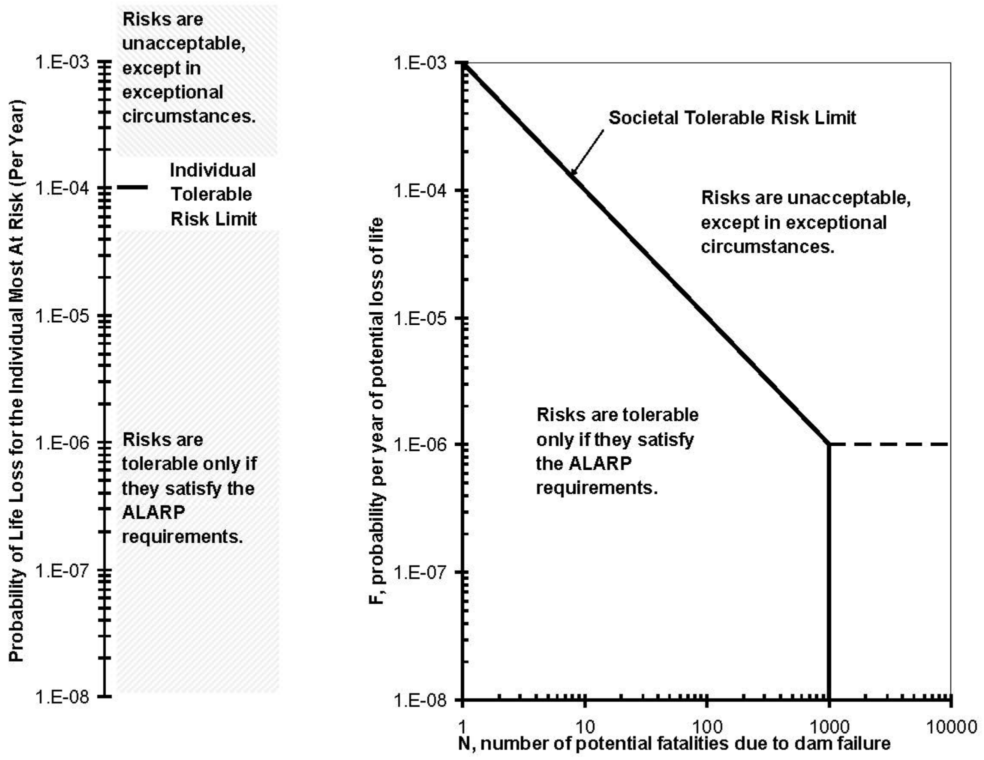
- Societal tolerable risk
  - MAF of death in a car accident
    - 1/10000 (1E-4)
  - MAF of building collapse
    - 1/5000 (2E-4)
  - MAF of death due to dam failure
    - 1/10000 (1E-4), existing dam
    - 1/100000 (1E-5), new, major dam
- Need to right size the F-C chart



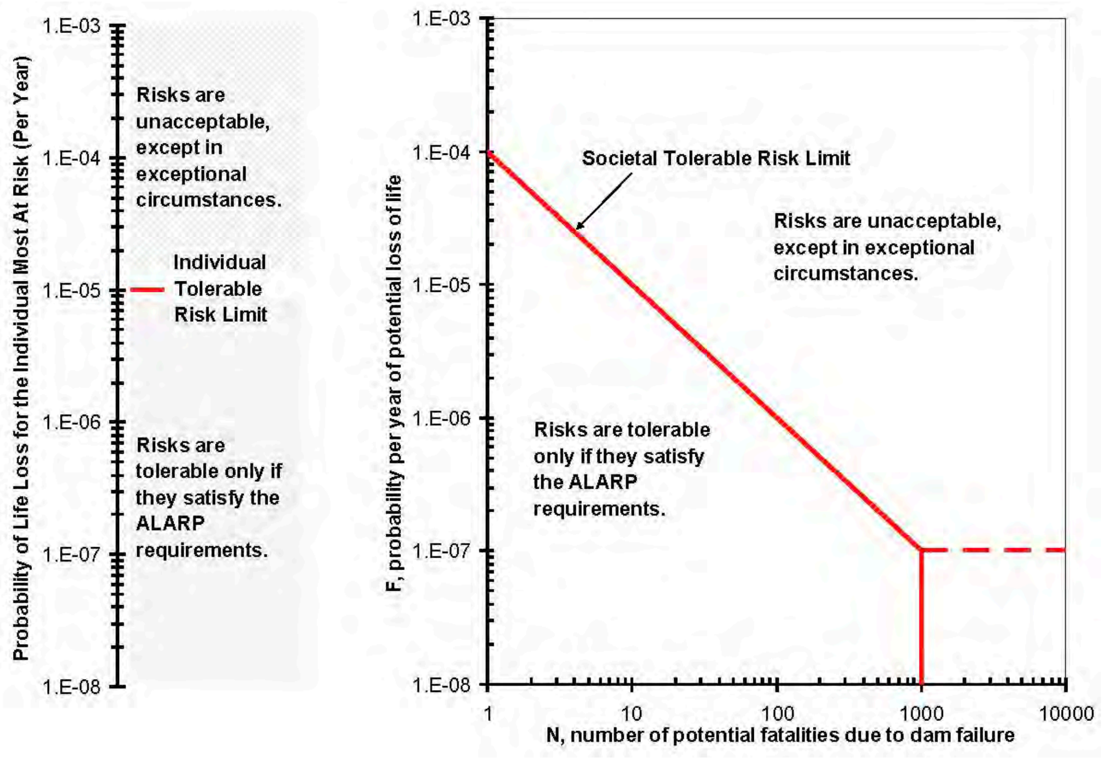
awhittak@buffalo.edu

Treatment of risk in other sectors: dams

Munger et al. (2009), USACE



Existing dams



New dams

Approach for Risk-Informing IEEE Standards

Rebecca Steinman, PhD, PE

Chair: SC-3, WG 3.4 and WG 2.10

09-13-2023

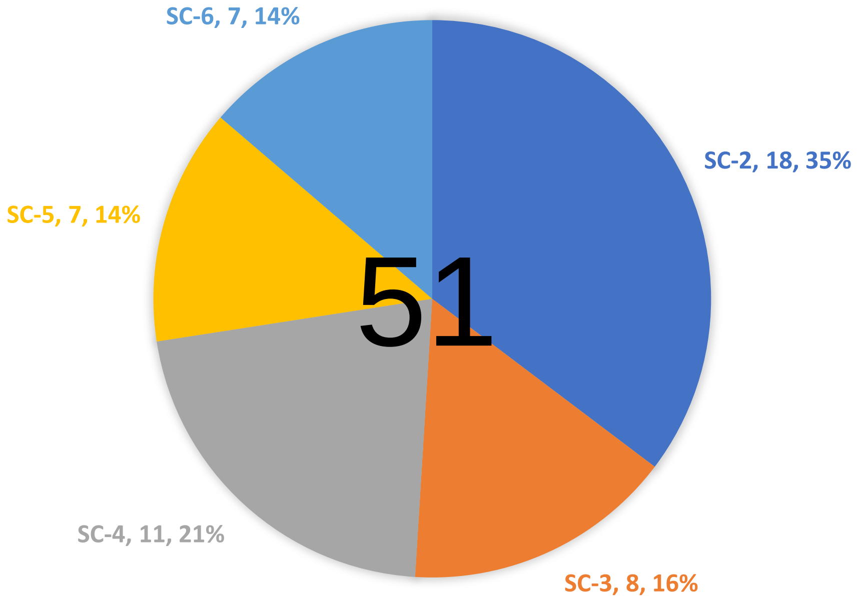
IEEE PES Power & Energy Society®

IEEE

Nuclear Power Engineering Committee (NPEC)

5 Technical Subcommittees

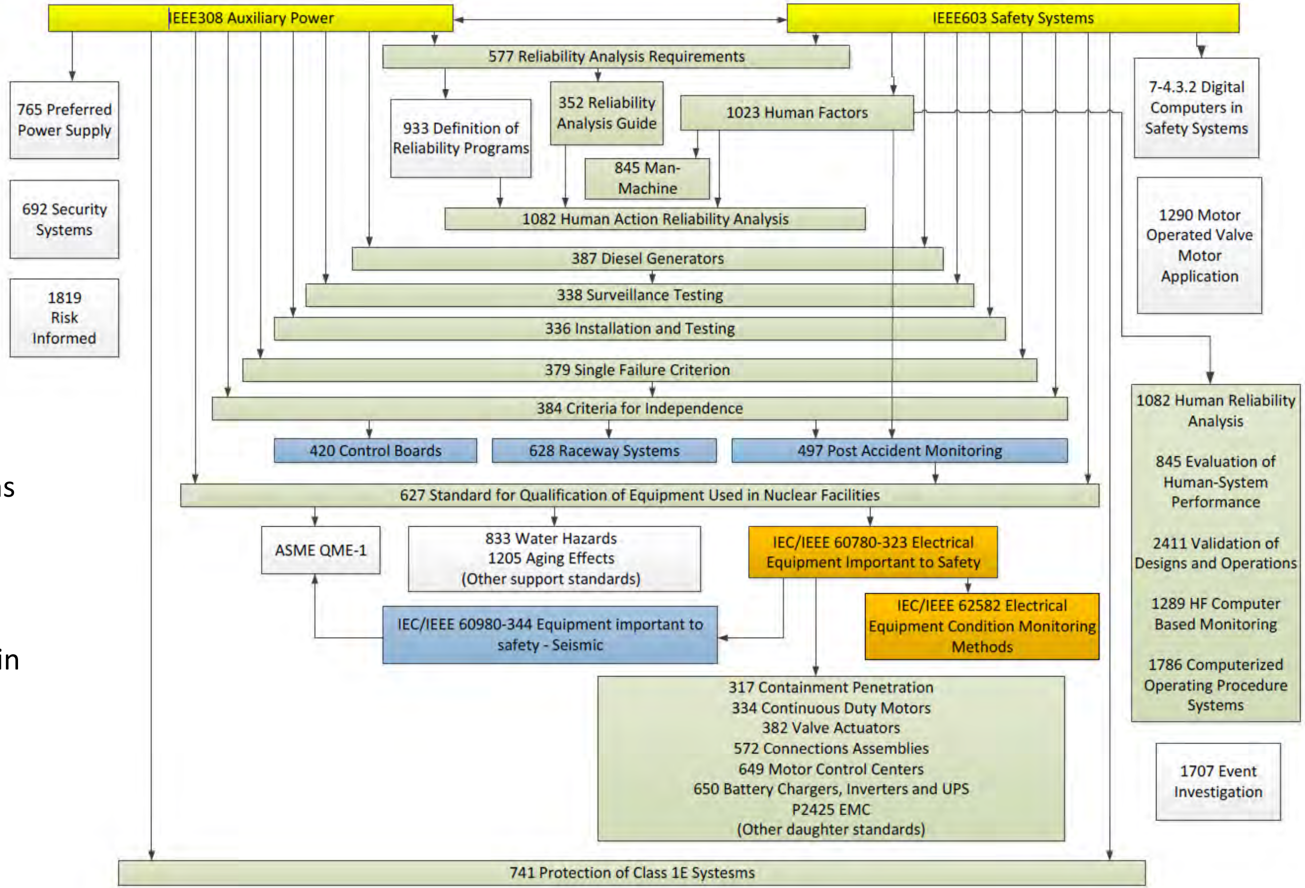
- Qualification (SC-2)
- Operations, Maintenance, Aging, Testing & Reliability (SC-3)
- Auxiliary Power (SC-4)
- Human Factors, Control Facilities and Human Reliability (SC-5)
- Safety Related Systems (SC-6)



IEEE 336
IEEE 338
IEEE 352
IEEE 577
~~IEEE 692~~
IEEE 933
IEEE 1205
IEEE 1819

NPEC Standards Approach

- Majority of standards focused on design & qualification of electrical and electronic equipment
- Class 1E or not, as determined by IEEE 308, 603, and 497
- **Class 1E:** Safety classification of the electrical equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment.



IEEE

Risk-Informed Categorization & Treatment of Electrical Equipment

	Class 1E	Non-Class 1E
Safety significant	RISC-1 Class 1E Safety Significant (Current IEEE standards apply)	RISC-2 Non-Class 1E Safety Significant (Can have increased requirements)
Low safety significant	RISC-3 Class 1E Low Safety Significant (Alternate Treatment can be applied)	RISC-4 Non-Class 1E Low Safety Significant (No special requirements)

- **alternate treatments**: Those licensee-defined requirements applied to electrical and electronic systems and components (EESCs) that provide reasonable confidence that 1) RISC-3 EESCs are capable of performing their Class 1E functions under design basis conditions; and 2) RISC-2 EESCs perform their functions consistent with the key assumptions in the categorization process that relate to their assumed performance, as applicable.
- **reasonable assurance**: A justifiable level of confidence used to satisfy regulatory requirements, based upon objective and/or measurable evidence.
- **reasonable confidence**: A level of confidence based on facts, actions, knowledge, experience, and/or observations, which is deemed to be adequate. Reasonable confidence is a lower level of confidence than reasonable assurance.

Usage and Status of IEEE Standards

- 10 year revision policy of IEEE
- Desire for global harmonization of standards
- Operating plants stick to their original licensing basis (mostly the 70s and 80s versions)
- Near-term attempts to apply the updated standards often ended up reverting to prior versions because licensing the old standards was "easier"
- So even when we try to modernize a standard to the current state of knowledge we struggle with getting new reactor vendors or other users to commit to their use

∴ The decision to develop a single standard to "bridge the gap" as opposed to significant revision of 50 standards remains the right approach for IEEE.

NEI Codes and Standards Task Force

NRC Standards Forum 2023

Thomas Basso
Sr. Director Eng & Risk
September 13, 2023

NUCLEAR ENERGY INSTITUTE

A Risk-Informed Journey

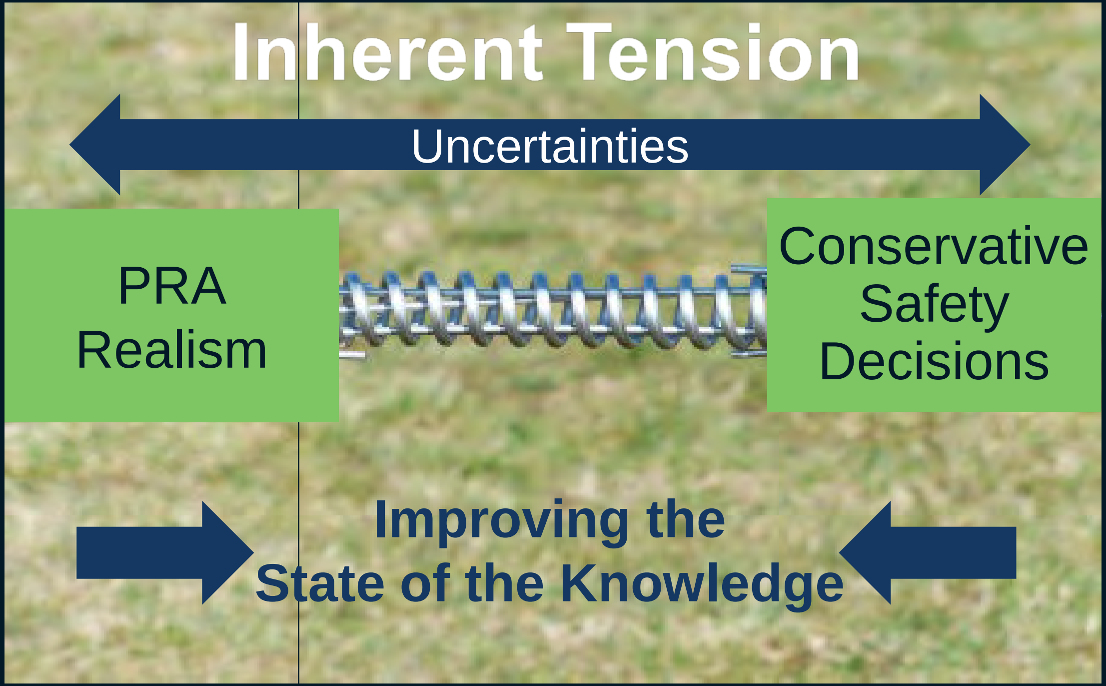
- Risk informed approaches have provided a better safety focus, improved safety and enabled efficiencies
- As we look to the future fleet, there are opportunities for risk-informing the regulatory fabric that come with both promise and attention
- Navigating this change will require embracing uncertainties and discipline in responding

1995 PRA Policy Statement

The use of PRA technology should be increased in all regulatory matters *to the extent supported by the state-of-the-art in PRA methods and data* and in a manner that *complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy.*

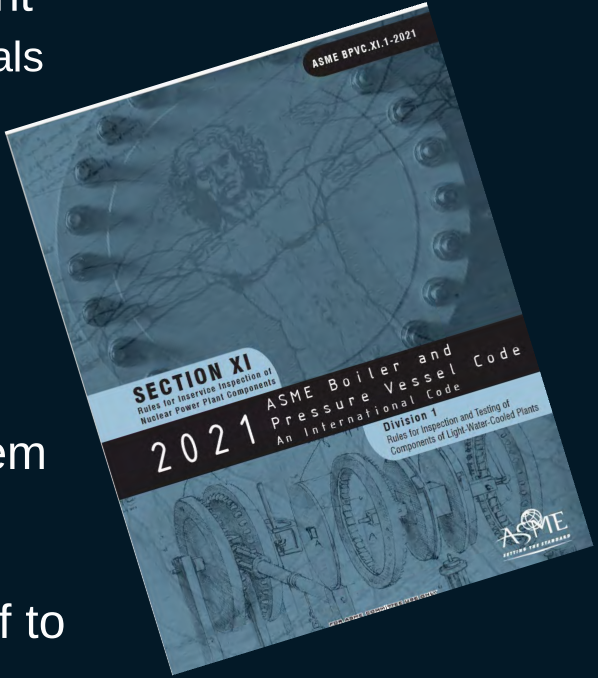
PRA is an expression of our state of knowledge

Risk-informed Regulatory Decision-making



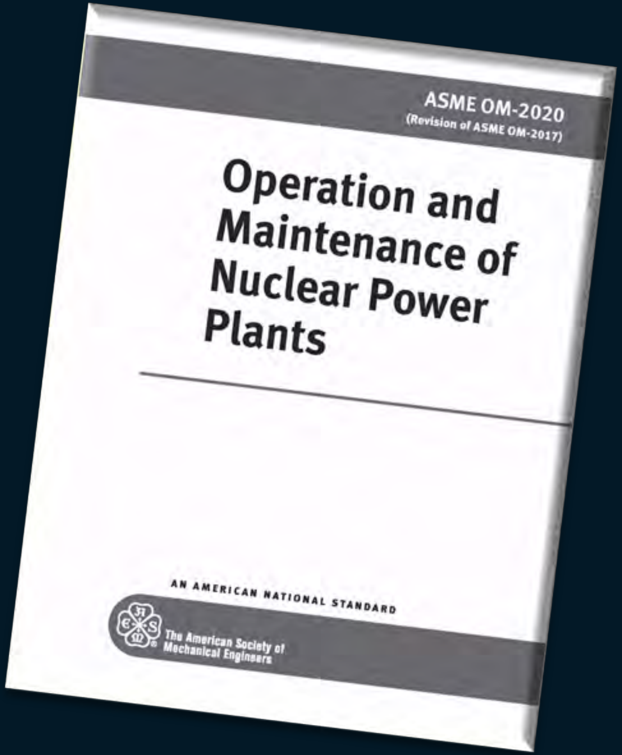
ASME Section XI Code Activities

- Code Case N-752 Risk-informed Repair/Replacement
  - NRC Endorsement and Approval of 50.55a(z) Submittals
- IWA-4000 Repair/Replacement Optimization
- Alternative VT-2 Qualification
  - Establish appropriate training hours requirements
- IWE General Visual Examinations (Category E-A, Item E1.11) Insulation Removal – Industry Survey
- Application of EPRI Tech Bases using PFM for Relief to Extend SG/PRZ Nozzle Weld Inspections

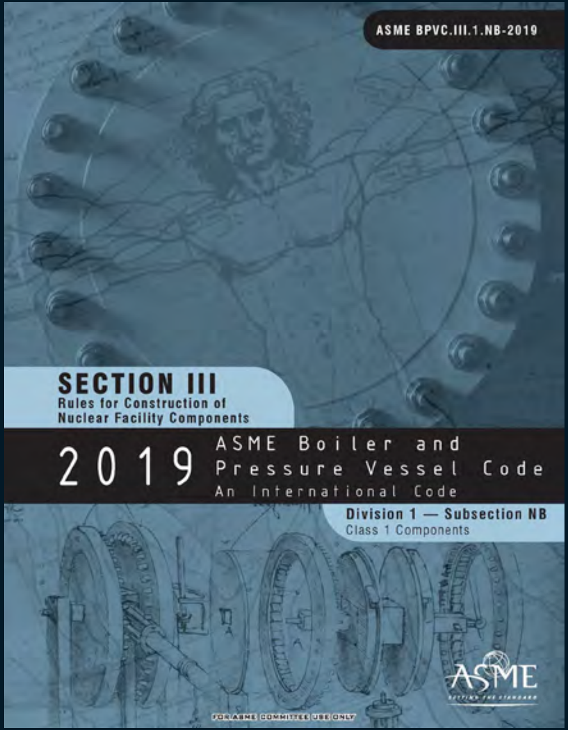


ASME OM Code Activities

- Valve Exercising and Testing Requirements
  - Valve Manual Exercising Frequency Extension
  - Revise Testing of Passive Valve
  - Quarterly Valve Stroking Extension
- Risk-informed Applications
- Replacement of “Operability” Term in OM
- (OM-2) Code on Component Testing Requirements



ASME Section III CSTF Activities



- TG Alternative Treatment Requirements
  - Code Case on Alternate Requirements for NDE and Testing of Items Commensurate with their Contribution to Safety and Risk
- ASME III CC N-907 and Code Change on Preservice Inspection Requirements
- Regulatory Engagement on ASME Section III Priorities

NEI CSTF Regulatory Activities

- **10 CFR 50.55a Rulemaking Review** (NRC-2018-0289)

- **Reg Guides 1.147, 1.84, 1.192, and 1.193 Comments** (NRC-2018-0291)
  - Extension of 10-year ISI/IST Program Updates
  - Extension of ISI Intervals from 10 to 12 Years

- **Response to NRC RIS 2022-02 on Operational Leakage**
  - NEI 18-03 Operability Guidance

EPRI Activities Supporting RIPB Standards

2023 NRC Standards Forum

Eric Thornsbury
Principal Technical Leader

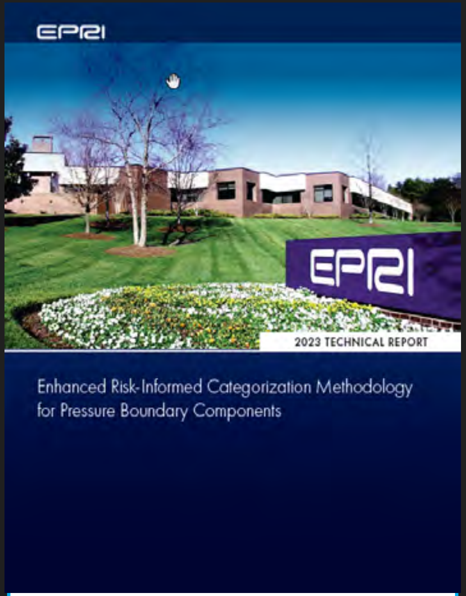
September 13, 2023

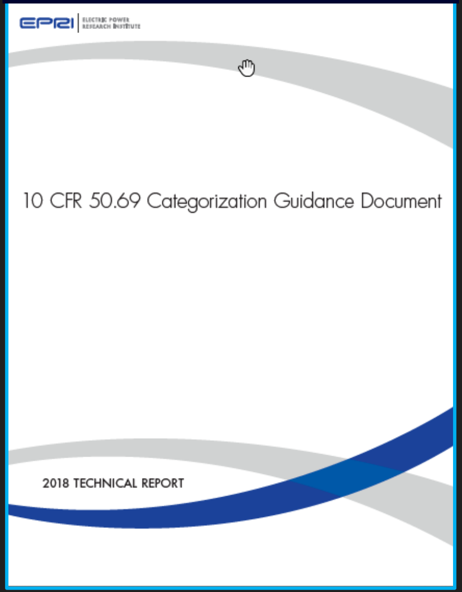
Introduction

- EPRI participates in many activities related to the development of standards across the nuclear industry
- Interest in Risk-Informed, Performance-Based applications (including standards) has been increasing, and is getting additional attention due to activities related to our Advanced Nuclear Technology program
- Key Question for Advanced Reactors:
  - How to meet current regulations, standards, and other expectations that were developed from a light water reactor perspective?

Examples of EPRI Activities for the Current Fleet

- RPV Threads in Flange (EPRI Report #3002010345)
- N715 for Streamlined RI-ISIN (EPRI Report #3002003026 on BWR and PWR Lessons Learned)
- ASME Section XI - Appendix R, Supplement 2 was included in the last rulemaking on 50.55a
- N711 for Inservice Inspection (EPRI Report #3002010353)
- Risk-informed Repair / Replacement (EPRI Report #3002013126)
- 10CFR50.69 (EPRI Reports #3002012984, 3002012988, 3002012990, 3002022453, 3002015999, …)





Strategic Elements of the EPRI/NEI AR Roadmap

Regulatory Efficiency

- **Licensing** – 7 Actions
- **Environmental** – 7 Actions
- **Oversight** – 2 Actions

Technology Readiness

- **Fuel Cycle** – 3 Actions
- **Plant/SSC Design** – 3 Actions
- **Supply Chain** – 7 Actions
- **Nuclear Beyond Electricity** – 3 Actions
- **Codes & Standards** – 2 Actions

Project Execution

- **Project Management** – 4 Actions
- **Engineering & Procurement** – 2 Actions
- **Construction & Commissioning** – 3 Actions
- **Initial Operations & Maintenance** – 1 Actions
- **Workforce Development** – 4 Actions

EPRI's Strengths

Plant Operation & Maintenance

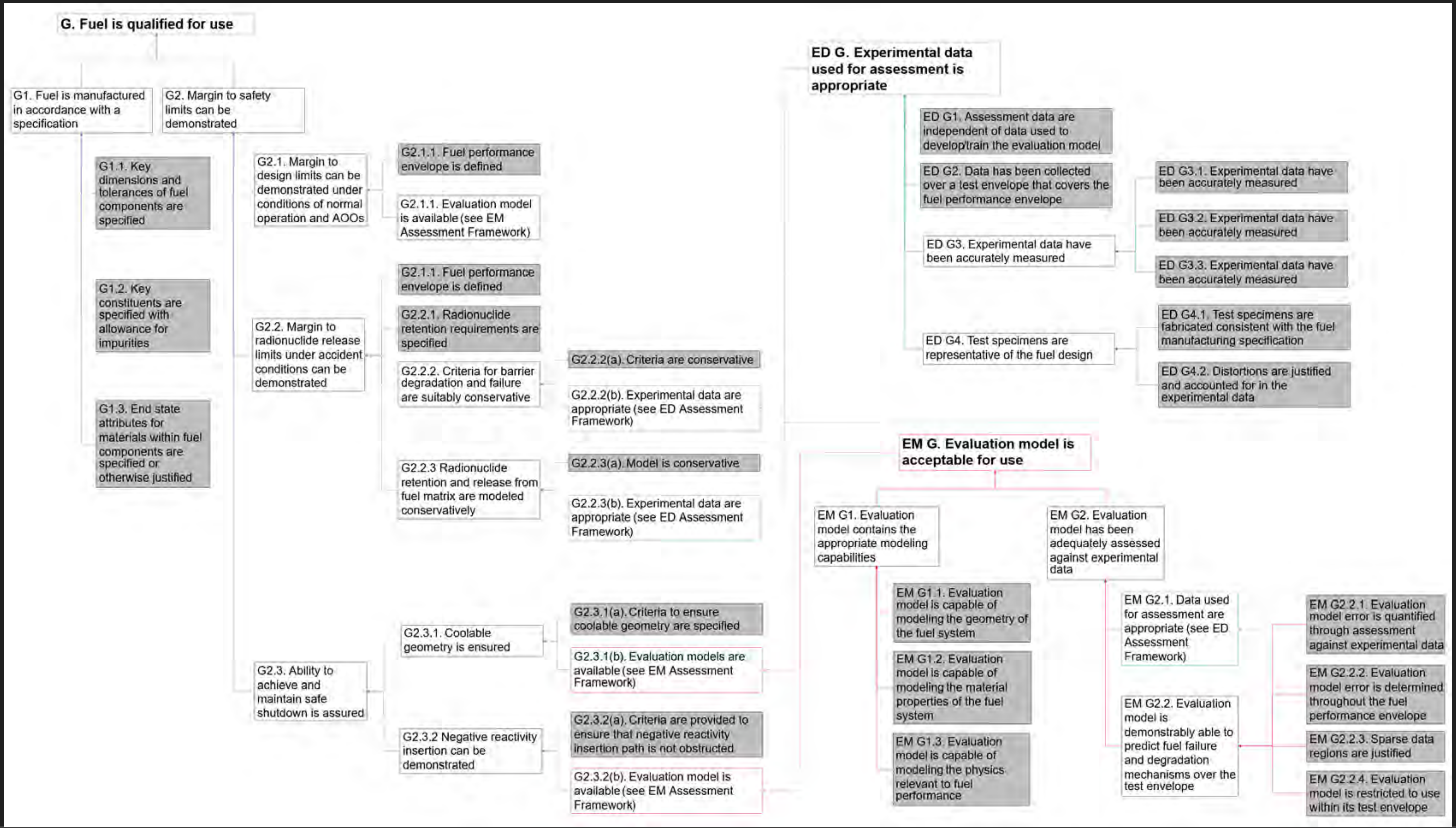
Component Manufacturing

- Technical Process Guidance
- Technical Methods Development
- Efficient Tools and Software
- Technology Transfer and Member Support

Standards Development

Regulatory Guidance & Interface

Example: Fuel Qualification from NUREG-2246

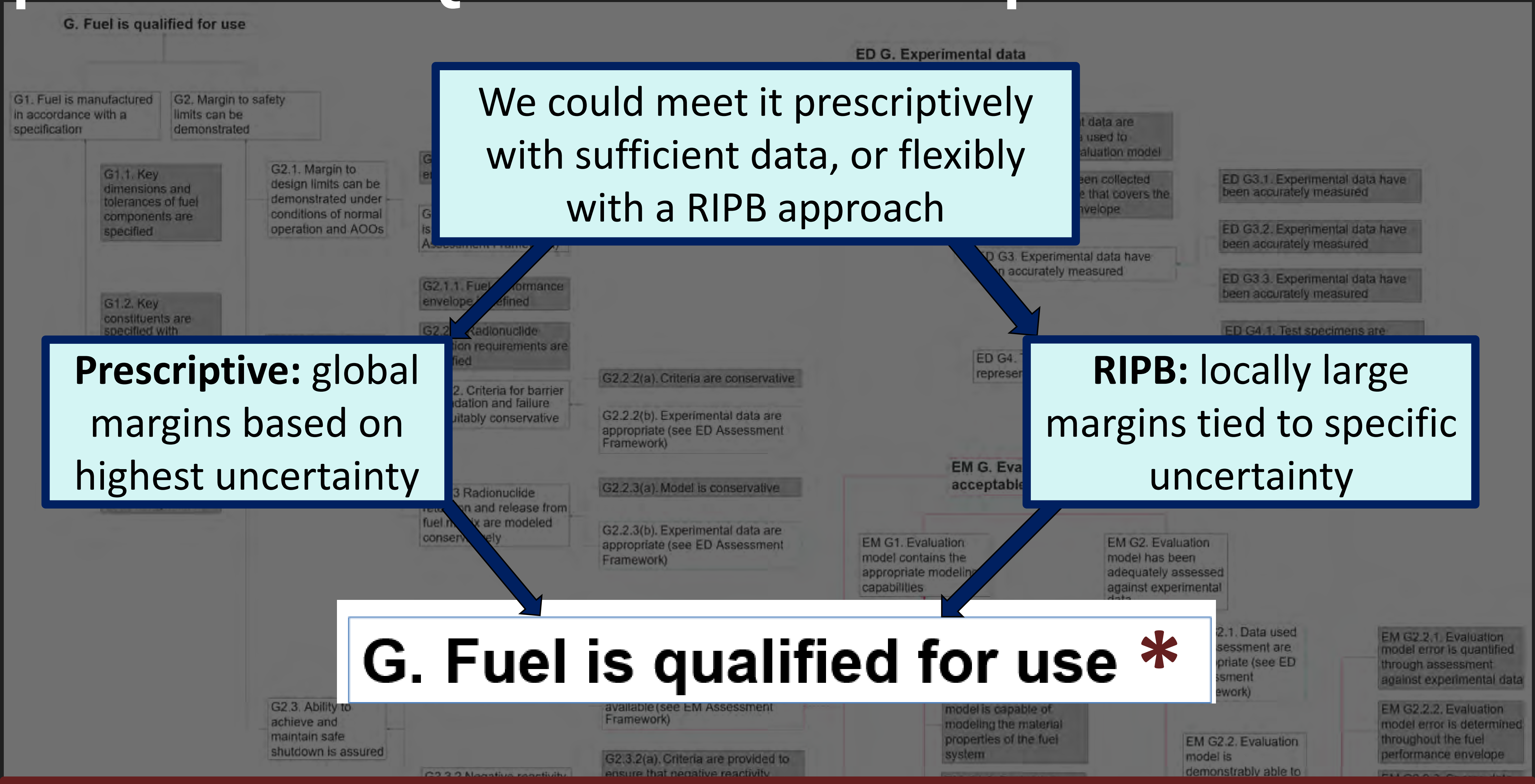


Example: Fuel Qualification for an Advanced Reactor

G2.3.1. Coolable geometry is ensured

- Geometry for a Liquid Fueled Reactor is…difficult to define!
  - The fuel does not have a defined geometry of its own
  - What are we really ensuring?
  - If the intent is to show that we can cool the fuel, perhaps the underlying purpose is that we show that the fuel is in a coolable form (but not necessarily a fixed geometry)
- Prescriptive interpretation of this requirement could break down, but RIPB can satisfy the intent!

Options for Fuel Qualification for a Liquid Fueled Reactor



We could meet it prescriptively with sufficient data, or flexibly with a RIPB approach

Prescriptive: global margins based on highest uncertainty

RIPB: locally large margins tied to specific uncertainty

G. Fuel is qualified for use *

***Prescriptive provides certainty; RIPB provides flexibility to meet the same intent**

EPRI Evaluation of Risk Analysis Methods & Tools for ARs

1. Determine the readiness of current PRA* methods and tools for use in Advanced Reactors and identify technical gaps that can be resolved through EPRI research
2. Develop an EPRI research roadmap to guide EPRI research in this area over the next several years to ensure readiness of PRA methods and tools for Advanced Reactor community implementation
3. Perform research and development based on the first two objectives to resolve key technical gaps in PRA methods and tools for the Advanced Reactor community.

"PRA" terminology represents a broad range of Risk approaches

EPRI Evaluation of Risk Analysis Methods & Tools for ARs

Challenges

- Risk analysis is an important input to final designs and initial licensing
- New technologies used in advanced reactor designs present new challenges to the existing risk analysis toolset
- Risk analysis for advanced reactors is expected to produce different results and insights than the current fleet and regulators are familiar with
- The current risk-informed decision-making approaches may not be a realistic approach for advanced reactors

Solutions

- Common methods, tools, and data that support realistic risk analysis in support of design and licensing activities
- Streamlined risk analysis approaches, results, and insights that are appropriate for advanced reactors

EPRI Support for the AR Roadmap Action:
Demonstrate Risk-Informed & Performance-Based Approach

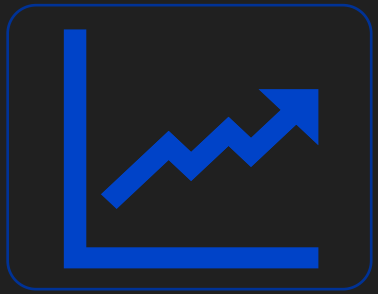
2023

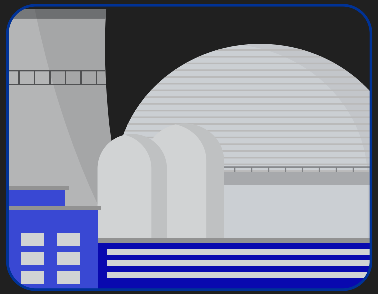
- Evaluate Risk Methods & Tools
- Guidance for Selecting Risk Metrics
- Risk Assessments with Digital I&C Systems
- Guidance for Very Low Freq. External Events
- Common Approaches for Passive System Reliability
- Human Reliability Analysis Methods for ARs
- Data Needs for Advanced Reactor Risk Analysis
- Methods for Economic Risk Analysis

EPRI Report - 3002026495 - Evaluation of Risk Analysis Methods & Tools for Advanced Reactors

Summary

- EPRI supports the development of RIPB standards and related activities
- RIPB approaches offer the needed focus and flexibility for Advanced Reactors to safely and efficiently design, license, and operation
- Uncertainties, both technical and regulatory, need to be acknowledged and addressed as part of any RIPB application






Together…Shaping the Future of Energy®